THE ROCKS OF NOYANG.

BY

A. W. HOWITT, F.G.S.

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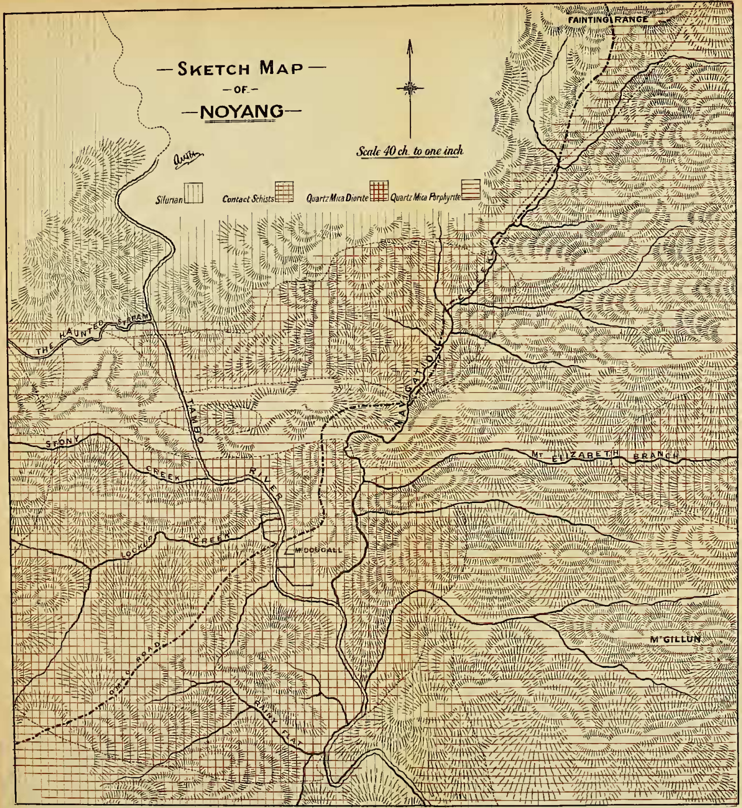

— SKETCH MAP —
— OF —
— NOYANG —
Scale 40 ch. to one inch
Silurian
Contact Schists
Quartz Mica Diorite
Quartz Mica Porphyrite
FAINTING RANGE
THE HAUNTED STREAM
TAMBO
STONY CREEK
RIVER
NAVIGATION
CREEK
Mt ELIZABETH BRANCH
LOCKUP CREEK
McDOUGALL
OMEO ROAD
RAINY FLAT
McGILLUN

Art. IV.—*The Rocks of Noyang.*

By A. W. Howitt, F.G.S.

[Read 10th May, 1883.]

I.—Introduction.

In a former paper I made the statement that I had observed, when tracing round the boundary of regional metamorphism at Omeo, the constant recurrence near it of tracts of intrusive igneous rocks.* The rocks which I described in that paper formed one of those areas; those which I am now about to describe constitute another.

Noyang, strictly speaking, is the native name of the place where the road from Bruthen to Omeo first crosses the Tambo River; but I have applied it, as it is locally used, to the whole tract delineated upon the sketch map which is attached to this paper.

In examining this locality it seems at first sight that the regionally metamorphosed schists of Omeo do not extend so far south as the northern boundary of the intrusive rocks of Noyang; but a more extended examination of the country to the north of that boundary, as far as Ensay, has caused me to see that the limits of the regional schists must probably be extended to the northern slopes of the Fainting Range. I am not now prepared with the evidence necessary to determine this question; indeed, it would be beyond the scope I have set myself in this paper, and may well wait until I have prepared, by an examination of others of the detached intrusive areas which border the regional schists, for a consideration of the latter.

It will be observed that in this paper I have followed the terminology and classification established by Professor Rosenbusch in his "Physiographie der Massigen Gesteine," and lately presented by him, in a more systematised form, in

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* "The Diorites and Granites of Swift's Creek." *Transactions of the Royal Society of Victoria*, Vol. XVI., p. 19.

a communication to the *Neues Jahrbuch.** In order to avoid confusion, and to connect the terms I here use with those which I made use of in former papers, I shall, where a difference exists, note the synonym in a footnote.

II.—Physical Geography and Geology of the District.

The tract of country which I have mapped takes in the valley of the Tambo River for three miles above and two miles below the crossing at Noyang.† To the east it includes the slopes of Mount Elizabeth Range, and to the west those falling from the watersheds between the Tambo River, Shady Creek, and the Haunted Stream. Mount Elizabeth is the culminating point of a great and rugged mass of mountains which fill in the fork between the Tambo and Tambarra Rivers to the extent of about one hundred square miles. This mountain rises to near 3000 feet above sea-level. At its northern extremity it descends steeply into a comparatively low-lying basin, worn out of the metamorphic schists and the intrusive rocks. Its steep and rugged ridges fall to the west into Navigation Creek, and to the east into a tributary of the Tambarra River; to the south the mountain separates into a number of great spurs covered almost wholly with nearly impenetrable scrubs, the haunts of a few wild cattle, and almost untrodden by the foot of man.

The part which I have examined and mapped forms but about one-fourth of the one hundred square miles covered by this mountain and its spurs; but, having seen its northern, eastern, and some parts of its southern sides, I think that my examination gives a fair sample of the whole.

The Mount Elizabeth chain stands in the contact of three great formations. To the north it is bordered by the extreme outliers of the regional schists; to the west there is the great recurring series of lower palæozoic slates and sandstones, with quartz veins in which are most of the gold workings of Gippsland; to the east is the extensive tract of country occupied by the various intrusive rocks of the Buchan and

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* N. J. M., 1882, Vol. I., Part II., p. 1.

† I am under great obligation to the kindness of Mr. A. Black, the Assistant Surveyor-General, and to Mr. W. H. Gregson, the Land Officer at Bairnsdale, for supplying me with tracings of official surveys of much of the Noyang locality. The remainder I have filled in from rough surveys made during the examination of the rock formations.

Snowy River districts, with their associated fragmental formations, tuffs, and lavas; and finally, to the south, the course of the Tambo River separates the lower palæozoic sediments to the west from a great extent of intrusive igneous rocks to the east.

III.—The Igneous Rocks.

The particulars which I shall detail in these pages as to the igneous rocks of Noyang admit of my now saying that they are members of a series which is precisely analogous to that of which granitite is the crystalline-granular type. In this the characteristic felspar is orthoclase, while in the Noyang series it is a plagioclastic felspar, and very frequently albite. The complete analogy between the two groups of rocks will be better seen when I come to the description of the varieties of igneous rocks at Noyang.

(*a.*) *The Quartz-Mica-Diorites.*

Almost the whole of the south side of the Tambo River is occupied by light-coloured crystalline-granular quartz-mica-diorites. They do not, however, extend up the course of the Tambo River for more than a mile above the Noyang crossing, where they adjoin a great mass of quartz-mica-porphyrite, of quartz-porphyrite, and of quartz-granophyrite, which there crosses the river and extends for several miles to the west along the course of the Haunted Stream. On the eastern side of the Tambo, at Noyang, these quartz-mica-diorites extend towards Mount Elizabeth for some distance, and there also adjoin porphyritic varieties of rocks of the same series. These porphyritic rocks have cut across the crystalline-granular quartz-mica-diorites, have sent out great masses into them, and also many strong dykes across them even far into the adjoining sediments. Higher up the course of a stream having its source in part of the Mount Elizabeth Range, and near the localities I have just mentioned, there are again large masses of a crystalline-granular character, which differ, however, in so far that they seem to be somewhat younger in period of formation than the quartz-mica-diorites which I have described, and are also comparatively wanting in the basic minerals (magnesia-iron-mica and amphibole) which characterise them. Some of these rocks might be classed as the analogies of the "micro-granitites." To the south-east the quartz-mica-diorites terminate at well-marked examples of crystalline and schistose hornfels in respect of which they are intrusive.

The quartz-mica-diorite is much decomposed over a large tract of country, which is worn into rounded ridges and rather flat gullies. Elsewhere it stands out in torlike masses, and is well seen in the river course where the excessive floods in the last fifteen years have laid it bare in innumerable places. In its fresh condition it is a hard and somewhat tough rock of a light colour.

I now proceed to the results of the microscopic and chemical examination of these rocks.

The sample which I selected as typical occurs at the crossing of the Tambo River at Noyang. The structure of the rock is wholly crystalline-granular, and the constituent minerals have been formed in the order in which I now describe them:—

1. *Magnetite* in rectangular crystals. It occurs mostly in the mica and amphibole crystals, and more rarely adjoining them.

2. *Magnesia-Iron-Mica* (*Haughtonite*). This mica occurs in very irregularly-bounded crystals or groups of crystals. The outlines, whether seen in sections parallel or perpendicular to the basal cleavage, are most irregular, often running out into narrow protuberances or retreating into deep hollows. In places portions are detached, being either parts of cleavage plates separated from but still accordant with the main mass, or else in other cases broken up into numerous small flakes and scattered at random in the adjoining spaces filled by quartz. The other constituent minerals, amphibole, felspar, and quartz, conform themselves to the outlines of this mica, and the first is associated with it, not merely adjoining, but occasionally more or less enveloped by it.

At first sight it seemed to me that, in places, the felspar crystals were partially surrounded by the mica as a later production; but further examination has satisfied me that this is only apparently the case, and arises through the mica crystals having in some cases been partially broken, and in others from the felspar crystal either having crystallised in a pre-existing hollow, or having become fitted partly into it during the movements of the magma before it cooled.

This mica becomes translucent in shades of brown, and is in sections perpendicular to the cleavage strongly dichroic in shades of colour from pale yellow to almost black. It is either uniaxial, or having so small an optic-axial angle as not to be distinguishable when examined in the most favourable cases under the microscope. by the staurescope. As a rule, it is poor in inclusions. The most frequent are magnetite, but I have met with instances when it contained rather numerous twinned grains of felspar, which had the look of having been broken from larger crystals. Rarely I have observed crystalline granules of quartz. The only other inclusions to be noted are a few apatite needles lying in the basal section, and a few minute colourless prismatic microliths.

The alteration of this mica is almost wholly to some form of chlorite. Scarcely an instance has come under my notice in these rocks—crystalline-granular or porphyritic—in which the mica has not shown traces of chloritisation. The change commences at the exterior, and extends between the cleavage plates towards the centre, and in some cases certain folia are more attacked than others. It may be said generally of all these rocks that their decomposition commences with the alteration of the dark-coloured iron-magnesia-mica, which is so common as to be characteristic of the whole group.

In order to determine the nature of this mica, I separated sufficient for examination from portions of the Noyang rock. It is jetty black in colour, with a somewhat vitreous lustre; rather difficultly separable into thin laminæ, and somewhat brittle, except in the thinnest flakes. Before the blowpipe it fuses rather easily, and becomes magnetic. In warm hydrochloric acid, it decomposes somewhat easily, the silica separating as white scales. The specific gravity I found to be unexpectedly low, viz., 2·81. The quantitative analysis yielded the following results :—

No. 1.—Iron-Magnesia Mica.

	Per cent.	Molecular Proportions.		Ratio.	
Fl	·66	·35	$Fl + SiO_2$	12·76	2·8
TiO_2	1·05*	·25			
SiO_2	38·66†	12·67			
Al_2O_3	19·00	3·69	R_2O_3	4·48	1·
Fe_2O_3	6·37	·79			
FeO	9·96	2·77	RO	8·84	1·9
MnO	·66	·18			
CaO	1·52	·54			
MgO	10·61	5·35			
K_2O	8·58	1·83	R_2O	4·23	·9
Na_2O	1·08	·35			
H_2O	1·85	2·05			
	100·00				

The bases in this mica are therefore in the following proportions:—

R_2O_3	RO	R_2O
1.	2.	1.

that is, it belongs to a group which Professor Rammelsberg ‡ classes as the third, including, among other micas, lepidomelane and the haughtonite of Dr. Heddle.§ Professor Heddle describes the mica to which he has given the name of haughtonite as occupying a position between biotite and lepidomelane, and he gives the oxygen ratio of the three species as follows:—

	Biotite.	Haughtonite.	Lepidomelane.
SiO_2	21·	19·	20·
R_2O_3	8·	10·	15·5
(ROR_2O)	15·	12·5	7·

The oxygen ratio of the Noyang mica is—

SiO_2	19·35
R_2O_3	11·25
(ROR_2O)	11·36

The relative proportions in which the silica and the sesquioxide and protoxide bases occur in the Noyang mica

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* TiO_2 is calculated out as sphene, which occurs with this mica.

† SiO_2 is estimated from the difference.

‡ "Ueber die chemische Zusammensetzung der Glimmer." C. Rammelsberg, N.J.M., 1881, p. 365.

§ "On Haughtonite—a New Mica," by Professor Heddle. *Mineralogical Magazine*, Vol. III., Part XIII., p. 72.

are not quite those which Dr. Heddle assigns to haughtonite. The Noyang mica stands, however, between biotite and lepidomelane, although not equidistant to each. Its physical characters and behaviour before the blowpipe and to hydrochloric acid remove it from biotite, and the relatively small amount of ferric oxide removes it from lepidomelane. It may be, however, considered as representing a compound of three-fifths biotite and two-fifths lepidomelane, and with such a composition its low specific gravity is more in accord.

Although the composition of this mica does not quite agree with that given by Dr. Heddle for haughtonite, it is sufficiently near to justify me, I think, in referring it to that variety of magnesia-iron-mica.

It is convenient at this place to speak of the alteration products of this mica.

Chloritic minerals are so extremely common in these crystalline-granular rocks that they may be looked upon as one of the most characteristic constituents. The rocks which I have examined in thin slices afford plentiful evidence of the manner in which the conversion of the magnesia-iron-micas into chloritic minerals has taken place. Sections of the rock which I have taken for illustration afforded me all stages from the merest alterations in the edges of the cleavage plates to the complete conversion of the mica into a chloritic pseudomorph. Chloritisation is attended by the elimination of ores of iron, which are deposited as magnetite either in the chlorite crystals themselves or in their neighbourhood.

The discussion of analyses given in this paper shows that this mineral is probably in some cases at least of the constitution indicated by the formula—

$$3\,SiO_2 + R_2O_3 + 5\,RO + 4\,R_2O$$

—that is, of chlorite. But the mineral, as might have been expected from its mode of formation, through the alteration of mica and of amphibole—perhaps not always under precisely the same conditions—does not seem in all cases to be of the same structure or composition. The chloritic minerals occurring in the quartz-mica-diorite under consideration I found to be uniaxial, or to have an extremely small optic-axial angle. I could not determine which it was, as no section was precisely parallel to the basal cleavage. In slices perpendicular to that direction it is dichoric in shades of bright green. The ores of iron, and perhaps also titanium, which are removed in the alteration of the mica, are not always redeposited in rectangular crystals or in granular masses. I have observed frequently in these chlorite pseudomorphs, that the magnetite (? titanic iron) has been placed in the basal plane as opaque black needles, either singly or in tufts or masses. It is very common for these needles to be arranged in more or less well-marked stellate groups, with rays including angles of approximately, or exactly, 30°. Such arrangements are only visible in sections parallel to the cleavage, while in sections perpendicular to it the needles only show as horizontally-arranged tufts.

The chlorite either fills almost exactly the space formerly occupied by the magnesia-iron-mica or amphibole in the less altered rocks, or in those which have been most altered it fills irregular spaces with cleavable or with radial masses. In many instances flakes of a chloritic mineral are to be found throughout the whole rock.

In selecting a sample of rock from which to extract the chloritic mineral for examination, I necessarily had to choose one in which the process of chloritisation from mica might be considered to be complete. This involved a partly decomposed condition of the rock generally; and I found, probably in consequence of this, that the selected mineral, although carefully extracted and examined under the lens, still contained impurities.

The chloritic mineral formed pseudomorphs after mica (probably haughtonite). Its hardness is 1·5 to 2·, specific gravity 2·785. Its colour is dark green, with a rather pearly lustre in the cleavage plates, and the streak is grey, with a tinge of green. Before the blowpipe it fuses at the edges of thin flakes to a black magnetic glass, and is decomposed easily by sulphuric acid and by hot hydrochloric acid, white scales of silica being set free. In every example which I examined in the process of selection I found minute portions of a colourless mineral so intimately mixed with the mass as not to be separable.

One of the crystals of which I prepared a basal cleavage plate as a microscopic object showed these two different minerals distinctly. One I observed to be green in colour, and of the character which I have described when speaking of the chloritic pseudomorphs after mica; the other a colourless radiating mineral, apparently monoclinic. There was very little more than a trace of free ores of iron in this example. Subjoined is the quantitative analysis:—

No. 2.—Chloritoid.

		Per cent.		Molecular Proportions.			Ratio.		
SiO_2	...	34·39	..	1·146	SiO_2	...	1·146	...	1·7
Al_2O_3	...	24·38	...	·473	R_2O_3	...	·650	...	1·
Fe_2O_3	...	14·17	...	·177					
FeO	...	1·81	...	·050	RO	...	·735	...	1·1
CaO	...	3·80	...	·135					
MgO	...	11·01	...	·550					
K_2O	...	1·64	...	·035	R_2O	...	·767	...	1·2
Na_2O	...	·95	...	·030					
H_2O	...	6·32	...	·702					
		98·47							

Hygroscopic moisture, 1·20 c 212° F.

Unless it were possible to isolate the impurities and to separate and examine each of the two component minerals, no certain conclusions could be drawn as to the real nature of the latter; but it may be possible by calculating the percentage to arrive at an approximation to the truth. The constitution of the rock from which the sample was extracted renders it most improbable that the impurities can be anything else than felspar and quartz; the examination which I have made of the Noyang igneous rocks renders it further most probable that the felspar is albite or an oligoclase very near to it. Thus the impurities may be calculated out, and the remaining molecular proportions should give the constitution of the mixed chloritic minerals. On this basis I have made the subjoined calculation. It raises a strong presumption that the mineral is a mixture of two of the chlorite group, one having the constitution of chlorite and the other of chloritoid. Under the microscope the former is colourless or white, and therefore probably free from iron; the whole of the iron therefore goes to form the latter.

CHLORITOID.

	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	CaO.	MgO.	K_2O.	Na_2O.	H_2O.	Molecular Proportions.	Per cent.
	1·146	·473	·177	·050	·135	·550	·035	·030	·702		
Albite	·180	·030	..	..	..	..	..	·030	..	·240	7·90
Chlorite	·078	·026	..	..	..	·130	..	..	·104	·338	7·21
Chloritoid	·594	·417	·177	·050	·135	·409	·035	..	·559	2·376	73·93
Quartz	·294	..	..	..	..	..	..	..	..	·294	8·82
Totals	1·146	·473	·177	·050	·135	·539	·035	·030	·663	3·248	97·86
Differences ..	..	..	..	..	..	·011	..	..	·039	..	..

Disregarding the impurities, this mineral may be considered as composed of nearly 9 per cent. of chlorite and 91 per cent. of chloritoid.*

The molecular proportions of the sesquioxide and protoxide bases in this chloritoid do not agree well with those of other chloritoids, the analyses of which I have been enabled to examine and calculate; † yet the whole mineral, including impurities, gives a formula which accords quite as nearly with that of chloritoid as do those of some of the analyses to which I refer.

This raises a doubt whether those analyses were not also of impure or mixed material. It is to be feared that in too many cases new species of chloritic minerals have been established by analysts on all too insufficient examination, and that mineralogical science has been overburdened with names that will ultimately have to be expunged.

This Noyang mineral, being a mixture, has not even a right to be called a mineral species. It is a mixture of chloritic minerals, and I doubt whether, strictly speaking, I am justified in calling it chloritoid in disregard to the percentage of chlorite it contains.

Amphibole. In these rocks amphibole constantly accompanies, but is subordinate to, the mica. As is the case with the latter, its crystalline planes are rarely observable. It is ragged, eroded, and seems in places to have suffered partial refusion at the edges and corners after crystallisation. Twinning is not very common, but when occurring is according to the ordinary law. The prismatic cleavage is well marked in sections across "c." Measurements of the obtuse angles in several sections gave me 124° 30′, 125° 10′, and 126° 15′. The colours, as seen by ordinary light, are shades of green.

The polychroism of this amphibole is well marked. I found it to vary through shades of yellow and green, and in some cases brown and bluish green. The colours of the three rays and the absorption I found to be as follows in one of the most typical sections:—

$c >$	$b >$	$a >$
dark green	light green	yellow.

In sections which were probably near the clinopinacoid, I found the angle formed by the plane of vibration to be as

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* A slight difference would be made if that portion of the felspar which is kaolinised were calculated out. This is so trifling as to be immaterial.

† Dana, *System of Mineralogy, with Appendices to* 1882; Rammelsberg, *Mineralchemie*, 1875; Heddle, *Mineralogical Magazine*, July, 1880.

high, in one case, as 22°, but in the majority of cases between 12° and 20°.

Besides these, which may be considered with some certainty as hornblende, I found occasional instances of a second amphibole of a somewhat different character. The most marked feature, at first sight, was that its crystalline masses included numerous fragments or imperfect crystals of twinned felspars of small size. The outlines of this amphibole are even more irregular than those of the just described hornblende. The polychroism is much less, and the angles formed by the plane of vibration are much higher, being in two good instances, which I measured, 31° 15′ and 35°. Marked features are the indistinctness of the prismatic cleavage, and a somewhat marked very closely placed striation, which seems to represent a separation rather than a cleavage. It seems to me that this mineral stands in the same relation to hornblende that diallage does to augite. It is more subordinate to the hornblende than both are to the magnesia-iron-mica.

The dark-coloured masses looking like included fragments of some rock which are very common in the Noyang quartz-mica-diorites, I found to be crystallisations of, mainly, the more basic minerals. I observed the amphibole to be well crystallised, frequently twinned, and strongly polychroic. The prismatic angles measured in several cases were precisely 124° 30′, taking the mean of several readings. The angles formed by the plane of vibration I found in the highest to be 22°.

Felspars. The felspars of this rock are characterised by being almost, if not all, plagioclase. They are well crystallised, excepting where they have become adapted during growth to the form of some mica or amphibole crystal. The twinning takes place according to the Albite, and also to the Carlsbad law. Sometimes the former alone, but more frequently both conjoined. In some crystals one half of the Carlsbad twin is simple, while the other is compound. Besides these twinned crystals there are some lesser ones which are not twinned. Of these some may be orthoclase, but I found only one which had the optical characters of that felspar.

The mean of a number of measurements of the angle formed by the plane of vibration gave the following:—

OP (001)	$\infty \bar{P} \infty$ (100)	... $\infty \breve{P} \infty$ (010)
5° 30′ ...	15° 45′	

These measurements suggest albite, but are not incompatible with oligoclase; and the discussion of the analysis of this rock causes me to favour the latter view.

A slice from a rock collected on the upper part of the Mount Elizabeth branch gave me favourable sections for optical measurements of the felspars, and I found these to be in the zone $OP - \infty \bar{P} \infty$ between 2° 30′ and 16° 45′. This, again, agrees rather with oligoclase than albite.

Quartz fills in the spaces left vacant by the previously described minerals. It usually is composed of several crystalline granules, and otherwise completely resembles the quartz in other crystalline-granular rocks of a granitic character. I observed as inclusions—(1) Magnetite crystals, (2) laminæ of mica, (3) felspar fragments, and (4) small colourless crystals, apparently monoclinic.

Sphene. This mineral occurs, but not so frequently as might have been expected. The examples which I have observed have been rough crystalline grains; and in only one instance did I observe a well-formed crystal of the characteristic double wedge-shaped form.

Apatite occurs in the usual small and somewhat lengthy prisms.

I carried out a quantitative analysis of a portion of the same rock from which the thin slices were prepared:—

No. 3.—Quartz-Mica-Diorites.

	Per cent.	Molecular Proportions.		Ratio.	
P_2O_5	·22	·03	} = SiO_2	19·23	4·1
TiO_2	·03	·01			
SiO_2	57·69	19·23			
Al_2O_3	15·65	3·04	} = R_2O_3	4·64	1·
Fe_2O_3	7·42	·93			
FeO	2·41	·67	} = RO	4·69	1·
MnO	tr.	...			
CaO	6·92	2·47			
MgO	3·10	1·55			
K_2O	2·37	·50	} = R_2O	2·52	·5
Na_2O	2·33	·75			
H_2O	1·59	1·77			
	99·73	30·95			

Hygroscopic moisture ... ·34
Specific gravity ... ... 2·779

The alterations which have taken place in this rock make it somewhat difficult to calculate satisfactorily the different mineral percentages. All that can be hoped for, in the absence of more precise knowledge of the composition of the alteration products, is to arrive at a fair approximation. The analysis of the mica affords some light; but I found that on analysis the hornblende would not give reliable results unless that mineral were separated by methods which I had not at command. In the following calculation I have disregarded the small amount of chloritic alteration, and also the minute plates of some micaceous mineral, one of the alteration products of the felspars:—

QUARTZ-MICA-DIORITE.

	$P_2.O_5$.	Ti. O_2.	Si.O_2.	Al_2 O_3.	Fe_2 O_3.	Fe. O.	Ca .O.	Mg. O.	K_2 O.	Na_2 O.	H_2 O.	Total Molecular Proportions.	Total per cent.
	·03	·01	19·23	3·04	·93	·67	2·47	1·55	·50	·75	1·77	30·95	..
Sphene	..	·01	·01	..	..	..	·01	..	..	..	..	·03	·09
Apatite	·03	..	..	..	..	..	·10	..	..	..	..	·13	·50
Soda Felspar ..	..	..	4·50	·75	..	..	..	..	..	·75	..	6·00	19·69
Lime Felspar ..	..	..	1·04	·52	..	..	·52	..	..	..	..	2·08	7·25
Magnesia-Iron-Mica	..	..	3·00	·50	·50	·45	..	1·55	·50	..	·50	7·00	23·10
Kaolin	..	..	2·54	1·27	..	..	..	..	..	..	1·27	5·08	15·30
Magnetite	..	..	..	..	·22	·22	..	..	..	..	..	·44	2·55
Hornblende.. ..	..	..	1·86	..	·26	..	1·86	..	..	..	..	3·98	12·87
Quartz	..	..	6·28	..	..	..	..	..	..	..	..	6·28	18·84
Total	·03	·01	19·28	3·04	·98	·67	2·49	1·55	·50	·75	1·77	31·02	100·19
Differences ..	..	..	·05	..	+ ·05	..	+ ·02	..	..	..	..	+ ·07	..

The analysis thus calculated assigns ·26 Mol. of R_2O_3 and 1·86 Mol. of RO bases to the hornblende. This may represent the truth so far; but it is not likely that these constituents consist wholly of ferric oxide and lime, but that portions of the alumina and magnesia would be included in the amphibole minerals.

Assuming, however, that this calculation sufficiently expresses the composition of the rock as it is, and that the kaolin represents the altered felspars, the following may be assigned as the probable percentage composition of the unaltered rock; and in this I have assumed that the unaltered condition of the felspars was that of an oligoclase of the constitution Al. 3 : An. 1.:—

Oligoclase	48·25
Magnesia-iron-mica	23·49
Hornblende	11·64
Magnetite	2·32
Quartz	14·01
Sphene	·09
Apatite	·50
	100·30

In this rock the ratio of the constituents is—

Felspar, 1·30 ; Quartz, ·42 ; RO Minerals, 1.

(*b.*) *Quartz-Mica-Porphyrites and Quartz-Granophyrites.**

Rocks of this class are confined to the eastern side of the Tambo River, excepting where, above the Noyang ford, a great offshoot of the main mass extends from near Mount Elizabeth to the westward of the river, and along the course of the Haunted Stream. Many strong dykes of these rocks also extend similarly westward, and it might even be said with truth that they radiate from the great central porphyritic masses of Mount Elizabeth. The relations of these quartz porphyrites and granophyrites to the older crystalline-granular diorites may be well seen in Navigation Creek and the Tambo River. They penetrate the latter either as masses, or as parallel or winding dykes. The crystalline-granular rocks are in many places cut off by the porphyrites, but there are also frequent instances where the

* Spherulitic quartz-porphyrite.

former become poor in mica or amphibole, and at the same time acquire a more porphyrite character by the appearance of isolated crystals of felspar or quartz, or of both.

Great portions of Mount Elizabeth, in fact masses which are mountains, are, it seems, entirely composed of such rocks as those I am now considering, and *in situ* they have an extraordinary resemblance to their close analogues, the quartz-porphyries. Rocks of this class are in contact with the sediments over as large an area as are the crystalline-granular quartz-diorites.

I have included the quartz-granophyrites in this section, for the reason that I have as yet found such rocks only as abnormal parts of the quartz-mica-porphyrites. At the Haunted Stream, for instance, the great mass of such rocks at its northern contact with the sediments, has the structure of a granophyrite.

Some of the larger dykes which proceed from the quartz-porphyrite masses across the crystalline-granular rocks also show this structure.

As I have already said, I have not found the granophyrite structure largely developed at Noyang; but it does not follow that it is not to be met with more frequently than I have found it. The area of the quartz-porphyrite rocks is so large, that my examination, which has been specially directed to the area surveyed, has only included it in part.

The results of microscopic and chemical analysis of these rocks are as follow. The first example which I shall describe was collected near the north-western contact in Navigation Creek:—

Under the microscope it shows a micro-crystalline granular ground-mass, wholly composed of felspar and quartz, together with very numerous bladed microliths of a light green colour, and these occur in both felspars and quartz. So far as I could make out from an examination of these minute minerals, I believe them to have been amphibole, but now almost, if not quite, converted into some form of chlorite.

In this ground-mass, and forming part of it, certain of its constituents are porphyritic:—

(1.) Small twinned crystals, or clusters of crystals, of felspars, in which I found optical measurements in the zone $OP - \infty \bar{P} \infty$ min. = 5°, and max. = 15° 15′, and certain simple sections, in which the angle formed by the plane of vibration was 14°. The composition of these twins was according to (*a*) the Albite law; (*b*) the Carlsbad law; (*c*) where the composition face is $\infty \breve{P} \infty$ with interpenetration of twins, so that a double twin is produced in which the two diagonally opposite are optically similar; and (*d*) the Albite law and the Pericline law combined.

(2.) Felspars which are not well crystallised, but which are certainly simple, and in some of which, so far as could be made out from an examination of such minute objects, obscuration occurred where the longer diameter was in accordance with the plane of polarisation of the nicol.

(3.) Very rarely small imperfect crystals of a chloritic mineral. Its characters are precisely those which I shall describe when speaking of the porphyritic minerals of "first consolidation" in this rock. These chlorite flakes are probably the alteration products of such detached flakes of mica as I have observed to exist in the quartz of the quartz-mica-diorite.

(4.) A few minute, colourless prisms, of a tetragonal habit, which polarise brightly, and become obscured when the plane of the nicol is parallel or perpendicular to their prismatic sides. In one instance the measurement of the angle $\infty P \wedge P$ gave me 132°. These crystals are certainly zircon.

The porphyritic minerals of the first consolidation are as follow:—

Felspars. These are compound crystals, usually twinned according to the combined Albite and Carlsbad laws. The edges and corners are mostly rounded off or broken. They also form groups of several crystals, adjoining each other with their fractured ends. The angles of obscuration I found to be in the zone $OP - \infty \bar{P} \infty$ 5° 45′ to 16° 15′. These porphyritic felspars are somewhat altered, being not only kaolinised to some extent, but also full of minute flakes of a pale green colour, a mineral probably of the chlorite group. The optical and physical properties of these felspars may point to oligoclase rather than to albite.

Quartz occurs in more or less perfectly formed but often corroded and fractured crystals, with hexahedral outlines, and their character is precisely that so familiar to observers in the quartz of the quartz-porphyries.

Chloritic Minerals. Besides these there are a number of crystals of a chloritic mineral of about the same size and relative number as those of quartz. These are evidently the alteration products *in situ* of a magnesia-iron-mica, but in not one instance in the slices I prepared of this variety of rock did I find any portions of the original mineral remaining intact. Yet after carefully observing the various stages of alteration from mica to chlorite in the crystalline-granular rocks of this group, I cannot feel any doubt that this also is merely a secondary mineral. It occurs either in more or less well-defined hexagonal or rectangular sections. The former undergo no change of colour or of tint when examined over the polariser alone, while the latter are more or less markedly dichroic. The ray which traverses the crystal in the direction of the axis "c" is almost colourless, while that perpendicular to it is of some shade of green. It is, however, very rare to find one of these chlorite sections homogeneous throughout. The basal section, when examined between crossed nicols, usually shows a more or less wide margin, which behaves like an isotropic or uniaxial mineral when seen in the direction of the optic axis, while more or less of the central part is doubly refracting. The sections perpendicular to the cleavage planes show similar features; the green outside edges of the plates become wholly obscured when their fibrous structure is parallel to the plane of the nicol, while the colourless central parts show strong chromatic polarisation, resembling that of potassa-mica, and in no position are the numerous fibrous aggregates simultaneously obscured, nor could I find any fibres that behaved otherwise than would do those of a triclinic mineral. This suggests a colourless chloritic mineral, perhaps Leuchtenbergite. In the cleavage planes there have been deposited ores of iron and perhaps titanium.

In order to learn something more as to the nature of the porphyritic felspars and of the chlorite pseudomorphs, I digested a slice of this rock with occasional boiling in hydrochloric acid for nearly a month. On then examining it I found that the hydrated iron ores had been removed from the slice, leaving it altogether much clearer and more translucent than before. The chlorite pseudomorphs were somewhat bleached, and some of the folia were more attacked than others, but a great part of the black amorphous substance in the chlorite was unaffected, and could therefore not be magnetite.

The porphyritic felspars were not only not affected, but were much brightened by the removal of minute alteration products; but there was one exception, where part of the porphyritic crystal had evidently been replaced by some carbonate—probably calcite—and had been totally removed, leaving the ragged-edged cavity usual in such cases. The ground-mass of felspar and quartz granules was wholly unattacked.

The result, therefore, of this test has been to show that if any difference exists in the power of resistance against alteration between the porphyritic felspars and the felspar granules of the ground-mass, it is in favour of the latter. We have another instance of the rule that the earlier consolidated felspars are the more basic.

The following is an analysis of this rock:—

No. 4.—Quartz-Mica-Porphyrite.

	Per cent.	Molecular Proportions.		Ratio.	
P_2O_5	tr				
SiO_2 ...	72·39 ...	24·13	SiO_2 ...	24·13 ...	8·4
Al_2O_3 ...	14·42 ...	2.80	R_2O_3 ...	2.87 ...	1·
Fe_2O_3 ...	·56 ...	·07			
FeO ...	·30 ...	·08			
MnO ...	·01 ...	—	RO ...	1·31 ...	·4
CaO ...	·85 ...	·30			
MgO ...	1·85 ...	·93			
K_2O ...	1·23 ...	·26			
Na_2O ...	5·93 ...	1·91	R_2O ...	3·42 ...	1·2
H_2O ...	1·13 ...	1·25			
	98·67	31·73			
Hygroscopic moisture		·55			
Specific gravity ...		2·632			

Taking the microscopic examination as the basis, the above may be calculated into mineral percentages as follows:—

QUARTZ-MICA-PORPHYRITE.

	SiO_2.	Al_2O_3.	Fe_2O_3.	Fe. O.	Ca. O.	Mg. O.	K_2O.	Na_2O.	H_2O.	Total of Molecular Proportions.	Total Per cent.
	24·13	2·80	·07	·08	·30	·93	·26	1·91	1·25	31·73	..
Soda Felspar ..	11·46	1·91	..	..	..	..	..	1·91	..	15·28	50·15
Potassa Felspar ..	1·56	·26	..	..	..	..	·26	..	..	2·08	7·25
Lime Felspar ..	·60	·30	..	..	·30	..	..	..	..	1·20	4·19
Magnetite	..	..	·07	·07	..	..	..	..	..	·14	·81
Chlorite	·57	·19	..	·01	..	·94	..	..	·76	2·47	5·25
Kaolin	·28	·14	..	..	..	..	..	..	·14	·56	1·69
Quartz	9·66	..	..	..	..	..	..	..	..	9·66	28·98
Totals	24·13	2·80	·07	·08	·30	·94	·26	1·91	·90	31·39	98·32
Differences ..	..	..	..	..	..	+ ·01	..	..	– ·35	– ·34	– ·35

Estimating the kaolin as representing alterations in the porphyritic felspars, and assuming these to have been of the constitution, Alb. 3, An. 1, we have ·88 molecules of oligoclase to be taken into consideration in deciding upon the probable condition of the unaltered rock; and similarly the chlorite may be calculated as magnesia-mica. The result of such a calculation gives the following as the probable percentage constitution:—

Felspar	63 36
RO minerals	8·18
Quartz	23·48
	100·00

And these constituents are in the following molecular proportion to each other:—

Felspar, 8·61; Quartz, 4·31; RO Minerals, 1.

Another example of a rock of this group I found as a dyke crossing Navigation Creek below the junction with it of the Mount Elizabeth branch. In its least weathered portions it is hard, compact, of a pale slate colour, and of a flinty appearance. With the lens there are visible here and there minute cleavage planes of felspar and glassy-looking granules of quartz.

Under the microscope I found it to have a micro-crystalline-granular ground-mass of quartz and felspar, in which were a few porphyritic crystals, and here and there slight traces of yellow basis. In this ground-mass there are innumerable bladed microliths of some chloritic mineral. These lie at all angles in the rock, are bent, twisted, and often ragged at the ends, and are of a pale green colour. The constituents of this ground-mass show in places traces of radial structure. The porphyritic crystals are rare and of the subjoined kinds:—

(1.) A single large porphyritic crystal of triclinic felspar, in which the two compound halves are composed of plates which are not continuous throughout. The optical angle of obscuration on each side of the composition face of the Carlsbad twin I found to be nearly 17°.

Three small compound twins are probably of the second order of consolidation.

(2.) The porphyritic-quartz crystals are also very rare, there being only two, and these are both much rounded and eroded at the edges.

Both the felspar crystals and the quartz I found to be surrounded by a margin of crypto-crystalline ground-mass, which gradually passed into the micro-crystalline-granular structure of the major part of the slice.

(3.) A few small chlorite pseudomorphs after magnesia-iron-mica are scattered through the ground-mass. The character of this mineral is precisely that already described.

This rock, therefore, clearly has been a quartz-mica-porphyrite, in which the porphyritic characters are only slightly marked, and in which the RO minerals are almost absent. It nearly represents the ground-mass of such a rock as that already described as typical of this group.

The following analysis and calculation of the mineral percentage is of a sample of this dyke :—

No. 5.—Quartz-Mica-Porphyrite.

	Per cent.	Molecular Proportions.		Ratio.	
P_2O_5	tr.	—			
SiO_2	77·66	25·89	= SiO_2	25·89	10·5
Al_2O_3	12·30	2·39	= R_2O_3	2·47	1·
Fe_2O_3	·61	·08			
FeO	·17	·05	= RO	·47	·2
CaO	·16	·06			
MgO	·73	·36			
K_2O	·19	·04	= R_2O	2·80	1·1
Na_2O	6·96	2·25			
H_2O	·46	·51			
	99·24	31·63			
Hygroscopic moisture		·33			
Specific gravity		2·634			

The following may be taken as the probable composition of this rock calculated into its component minerals :—

QUARTZ-MICA-PORPHYRITE.

	Si. O_2.	Al_2. O_3.	Fe_2. O_3.	Fe. O.	Ca. O.	Mg. O.	K_2. O.	Na_2. O.	H_2. O.	Total Molecular Proportions.	Total Per cent.
	25·89	2·39	·08	·05	·06	·36	·04	2·25	·51	31·63	..
Soda Felspar	13·50	2·25	..	..	..	..	..	2·25	..	18·00	59·04
Potassa Felspar ..	·24	·04	..	..	..	..	·04	..	..	·32	1·12
Lime Felspar ..	·12	·06	..	..	·06	..	..	..	..	·24	·83
Magnetite	..	..	·02	·02	..	..	..	..	..	·04	·23
Chlorite	·30	·04	·06	·03	..	·47	..	..	·40	1·30	3·00
Quartz	11·73	..	..	..	..	..	..	..	..	11·73	35·19
Totals	25·89	2·39	·08	·05	·06	·47	·04	2·25	·40	31·63	99·41
Differences ..	..	..	..	..	..	+ ·11	..	..	— ·11	..	+ ·17

This rock may be assumed to have had the following composition, if we assume that the alumina and the magnesia in the chlorite represent the mica:—

Felspar	61·50
RO minerals	3·10
Quartz	35·40
	100·00

And on this basis the molecular proportion would have been—

Felspar, 12·5 ; Quartz, 7·9 ; RO Minerals, 1.

Quartz-Granophyrites. The rocks which I have selected as illustrations of this subdivision of the group are the following:—

(1.) Contact of the quartz-porphyrite mass with the sediments at the Haunted Stream.

In the slices of this rock which I prepared I found but very little of a ground-mass such as that which I have described in the quartz-mica-porphyrites, but that which there is precisely resembles it in being a minutely fine-grained compound of felspar and quartz. The far greater part of that which in kindred rocks would go to form this ground-mass is here aggregated into radial spherulitic masses of felspar and quartz, which either form the whole or surround some central object, or are disposed in irregular groups round it. These central objects are in some cases quartz, in others felspar crystals, or even chlorite, which, however, cannot be regarded as an originally formed constituent. The structure of these spherulites is not usually regular, but may be described as being built up of several groups of radial crystals. In some few the optical accordance of the various parts is such that a more or less perfect black cross is observable by polarised light in the spherulite as a whole, but in most cases this is not the case, and there are independent portions of several discordant crosses in the whole. The quartz-crystals which form the centres of these spherulitic masses are precisely such as are found in the quartz-porphyrites. The felspars are all plagioclase, and are often fractured. In some cases I have observed two or three felspar fragments forming the nucleus of a spherulite. One very large instance I observed to be built up of four concentric portions. The centre was a large somewhat rounded crystal of quartz, having several of the characteristic sinuses; this was followed by a rather narrow envelope of felsitic basis; the third envelope was of radial masses of the usual spherulitic composition. The whole mass was surrounded by a very fine-grained crystalline compound of felspar and quartz, in which there were a few small radial spherulites.

Throughout the compound ground-mass are innumerable small, lengthened green or brown microliths, some bent or twisted, or with forked ends. They occur more frequently in the spherulitic than in the micro-crystalline-granular parts of the rock. So far as I could observe their direction of extinction forms a small angle with the longer diameter. This suggests that they are amphibole, and the original condition of the chlorite microliths which I have found to be so numerous in the ground-mass of the quartz-mica-porphyrites of this locality.

In this ground-mass are porphyritically (1) crystals of quartz, (2) crystals of plagioclase, (3) a few examples of chlorite pseudomorphs after magnesia-iron-mica. All these porphyritic crystals are of the character of those I have described as occurring in the quartz-mica-diorites.

(2.) A dyke crossing the road north of Noyang.

This dyke cuts across the quartz-mica-diorites about a mile from the ford, and is probably a continuation of one of the strong dykes which have been laid bare by floods in Navigation Creek, possibly even of the dyke which I have examined and analysed, as recorded on page 25.

In this sample the main mass is micro-crystalline-granular. In it are distributed small prisms of plagioclase and granules of quartz. Besides these there are spherules isolated and in masses. Some of these are composed only of radiating long and very narrow prisms; others are radiating bundles of fibres surrounding a central crystal of quartz or felspar; and others are formed of a radial hemisphere placed against a felspar crystal.

(3.) Rock at the ford at Noyang.

This rock is composed wholly of felspar and quartz. The constituents of the ground-mass are arranged in radial aggregates. When such an aggregate is placed in a certain position as regards the plane of polarisation, one or other of the constituents becomes wholly obscured at the same time, and the second constituent stands out in strong contrast. This structure, therefore, assimilates to that which is called "micro-pegmatoïde" by MM. Fouqué and Lévy. These spherulitic aggregates very often touch each other, while elsewhere they are so far apart as to admit the interposition of crystals of plagioclase or micro-crystalline masses of quartz and felspar. In some few instances imperfectly formed crystals of felspar form the centre of the aggregates; more rarely these latter are arranged in the manner described as "structure pegmatoïde." Quartz does not occur in this rock porphyritically.

No mica or amphibole is present, nor any alteration products which would indicate their former existence.

(c.) *Quartz-Porphyrites.*

These rocks are so intimately connected with the quartz-mica-porphyrites that they might with propriety have followed them in this description; but as I have considered these intrusive rocks in the order in which I believe them to have been formed, the quartz-porphyrites in their most typical examples find their place here.

These rocks I have observed as dykes cutting across the older igneous rocks. At a certain part of the course of the stream which is known as the Mount Elizabeth branch, it leaves the crystalline-granular quartz-mica-diorites of its upper valley, and flows over successive masses of breccias, of black vitreous-looking porphyritic rocks, of quartz-mica-porphyrites, and of masses and dykes of milk-white, close-grained quartz-porphyrites. These last I believe to be the youngest of the whole group, with the exception of the black, vitreous rocks (felsophyrite). It seems to represent the magma of these older rocks freed from the basic constituents which in them go to form the mica, amphibole, and magnetite.

I now give the results of microscopic examination and chemical analysis of these white quartz-porphyrites. The samples were collected from two localities :—

(1.) A slice prepared from this sample I found to be composed of felspar and quartz. In places the former showed a tendency to crystallise out in definite forms, showing that it had a slight priority in order of formation; but although these imperfect crystals showed twinning, I could not obtain any measurements of the angles formed by the planes of vibration in the twin halves. In the ground-mass there was one porphyritic crystal of plagioclase, but, unfortunately, the greater part of it was lost in preparing the slice. A few rare and slight traces of hydrated iron ore completed the composition of this rock.

(2.) This slice much resembled the last described, but in the ground-mass of quartz and felspar I observed several crystals of quartz of the kind so commonly found in these porphyrites. There were also some porphyritic crystals of felspar, which were so much kaolinised that all that can be said of them is that they were plagioclase. Finally, there were some slight traces of chlorite and much more hydrated iron ore distributed through the whole rock than in the other example.

It was unfortunate that this sample was the one which I selected for analysis, and which, being the more porphyritic, and the more altered by decomposition, of the two, was less well suited for the purpose I had intended.

The rock when examined in a hand sample has a compact, nearly milk-white appearance, with here and there slight ferruginous stains, and a few small quartz-crystals can be made out.

In the subjoined analysis the silica was not directly determined.

No. 6.—Quartz-Porphyrite.

	Per cent.	Molecular Proportions.		Ratio.	
SiO_2	... 78·77	... 26·26	= SiO_2	... 26·26	... 10·3
Al_2O_3	... 12·44	... 2·43	= R_2O_3	... 2·55	... 1·
Fe_2O_3	... ·95	... ·12			
CaO	... ·53	... ·19	= RO	... ·20	... ·08
MgO	... ·02	... ·01			
K_2O	... ·24	... ·05	= R_2O	... 2·53	... 1·
Na_2O	... 6·79	... 2·19			
H_2O	... ·26	... ·29			
	100·00	31·54			

Hygroscopic moisture ·14
Specific gravity ... 2·614

The calculation of the mineral percentage may be made as follows:—

QUARTZ-PORPHYRITE

	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	H_2O.	Molecular Proportions.	Per cent.
	26·26	2·43	·12	·19	·01	·05	2·19	·29	31·54	..
Soda Felspar	13·14	2·19	..	..	..	..	2·19	..	17·52	57·49
Potassa Felspar	·24	·04	..	..	..	·04	..	..	·32	1·12
Lime Felspar	·32	·16	..	·16	..	..	..	..	·64	2·23
Magnesia-Iron-Mica ..	·06	·01	·01	·03	·01	·01	..	·01	·14	·47
Kaolin	·06	·03	..	..	..	..	..	·03	·12	·36
Limonite	..	..	·11	..	..	..	..	·22	·33	1·08
Quartz	12·44	..	..	..	..	..	..	..	12·44	37·32
Totals	26·26	2·43	·12	·19	·01	·05	2·19	·26	31·51	100·07
Differences	..	..	..	..	..	..	..	—·03	—·03	+·07

This rock may be considered as essentially a compound of felspar and quartz. The percentage composition can be taken as follows in the unaltered rock, assuming the kaolin, as before, to represent the alterations in the felspar, and disregarding the hydrated iron ore :—

Felspar	61·91
RO minerals	·47
Quartz	37·62
	100·00

The molecular proportion of these minerals I find to be as follows :—

Felspar, 133·43 ; Quartz, 88·88 ; RO Minerals, 1·

It is to be noted that this rock not only consists essentially of felspar and quartz, but that the felspar is almost wholly albite, it being most probable that the K_2O is here isomorphous with the Na_2O in a triclinic form.

The following comparison of the constitution of the four allied rocks may now be made, and the increasing acidity of magma comes out clearly. The analysis No. 5 may be thought to nearly represent the ground-mass of the porphyritic members of the series :—

	Felspar.	Quartz.	RO Minerals.
Analysis No. 2 ...	1·30 ...	·42 ...	1·
,, No. 3 ...	8·61 ...	4·31 ...	1·
,, No. 4 ...	12·5 ...	7·9 ...	1·
,, No. 5 ...	133·43 ...	88·88 ...	1·

(*d.*) *Quartz-Felsophyrites.*

The locality where this rock occurs appears to have been a focus of igneous activity. It is here that the great mass of quartz-mica-porphyrite extends out westward with its associated dykes, first filling a wide space in the crystalline-granular rocks, and then separating them from the sediments. At this place it is also that the masses and dykes of white quartz-porphyrite have penetrated the older igneous rocks.

The felsophyrite masses seem to me, so far as I could make out in the absence of a detailed feature survey, to fill in a central position in regard to the above-mentioned formations, and to be flanked by masses of breccias, which at first sight have the appearance of being made up of angular fragments of compact porphyrites, but which on examination prove to be really portions of the metamorphosed palæozoic sediments of the district.

It remains uncertain which is the younger formation, the white quartz-porphyrite, or this felsophyrite, but I incline to consider the latter to be the younger of the two.

This rock is intensely hard and flinty in appearance, usually black or greyish black in colour, and shows exceedingly numerous included fragments of other rocks, which give to it a porphyritic appearance. I examined two samples which I collected as probably fairly representing the average character of the rock. The microscopic examination of the two samples gave me the following results:—

The first sample consisted of a very large proportion of a basis of various shades of yellow to brown, and which has undergone felsitic alteration. It shows flow structure in a beautiful manner, not only in the differently shaded bands of varied width, but also in narrow lines of black, opaque granules, or long and narrow black microliths (iron ores) which lie in the direction of the flow. Alternating with these bands of almost wholly basis are others which are crypto-crystalline, and resemble the ground-mass of the fine-grained porphyrites. In these crystalline bands there are, however, strings and patches of basis which show very distinctly when a Klein's quartz-plate is used for their examination. Although the crystalline bands are much smaller individually than those of basis, and in the aggregate do not probably make up more than one-fourth or one-third of the mass, yet in places they swell out to several times their usual breadth, and the individual crystalline grains become at the same time larger. Similarly, the bands of basis swell out and narrow in their course. The manner in which these bands divide and follow round the included fragments is very characteristic.

Included in these bands, but more especially in those of basis, are innumerable minute crystalline grains, some of which are of felspars, which in many cases are twinned.

In this ground-mass, if the term is admissible, are included many much larger fragments—

(*a.*) Angular masses of yellow glass, rendered in places almost opaque by iron ores.

(*b.*) Fractured and eroded crystals of quartz, such as are found in the quartz-porphyrites.

(*c.*) Felspars which are more or less fractured. Almost all of these are twinned. The optical measurements which I was able to effect gave angles between 4° and 19° for the zone $OP - \infty\bar{\bar{P}}\infty$; and in one crystal, which was perfect and simple with the planes $OP - P - \infty P$, I found the angle formed by the plane of vibration with the edge $\infty \bar{P} \infty - \infty \breve{P} \infty$ to be 5°.

The felspars are extraneous to the rock, being merely included fragments, and the optical measurements afford, therefore, very little information except as to the individual crystal in which the measurement was made. The second sample showed, microscopically, a large number of inclusions, and was not so black and flinty in appearance as the other. The colour was a greyish black, and I found the specific gravity to be 2·717. Under the microscope I observed its characteristics to resemble those of the former sample, but the basis to be much less in amount, while the bands containing opaque black bodies, the crystalline bands, and the foreign inclusions were proportionately greater. This rock has the following composition :—Bands of yellow basis, alternating irregularly with bands or streams of micro-crystalline materials. These bands are, as a rule, exceedingly narrow relatively to each other, but in places swell out to bunches, in which are usually contained angular fragments of foreign substances, such as quartz or felspar. In this ground-mass are—

(*a.*) Angular fragments of quartz-crystals.

(*b.*) Angular fragments of micro-crystalline-granular quartz-porphyrite.

(*c.*) Felspar crystals similar to those spoken of in describing the last sample. The most peculiar feature in these felspars is their conversion in some parts almost wholly into a pale green mineral, having the optical characters of epidote. This alteration, or more properly substitution, product also occurs in several flows which traverse the slice.

(*d.*) Two comparatively large masses of fine-grained sandstone are also included. These have precisely the characters of the hornfels produced by the metamorphism of the quartzose sediments of the district.

(*e.*) Finally, traces here and there of some chlorite mineral.

This rock may therefore be described as a felsophyrite, having a ground-mass which, probably, if found free from included fragments, would represent "pitch-stone."

The composition of this rock, being made up so much of extraneous materials, decided me not to take the trouble of making a quantitative analysis, as it seemed that no results of value would be likely to be attained.

The mode of occurrence of these black and vitreous rocks entirely among the crystalline-granular and porphyritic members of the series suggests that they represent the plug of a vent which emitted a lava that included numerous extraneous fragments, partly derived from below and partly from the volcanic dust which had fallen back again into the orifice. The fact that it is from this locality that the quartz-porphyrite dykes and dyke-like masses radiate, lends strength to such a supposition.

(*e.*) *Diorites.*

Traversing the quartz-mica diorites and porphyrites, but not so far as I know in connection with the later igneous rocks, there are numerous dykes which are all marked by a dark greenish colour and a finely crystalline structure. They are good examples of rocks which were formerly all classed as "greenstones," and which, as dykes, are very common in the Gippsland mountains. There is little in their occurrence to show whether they do or do not belong to the series of rocks which I have now described; but they certainly do appear to be more plentiful in the area of igneous rocks than outside of it; and I have observed the same fact elsewhere; for instance, at Swift's Creek, where dykes of very basic character, being mainly amphibole, traverse the quartz-diorites, and are, I think, connected with the intrusive areas of amphibole rocks (Schillerstein) which are the youngest of all the series which, together collectively, constitute the intrusive area at that place. An instance of these dykes occurs at Navigation Creek, in the quartz-mica-diorites. It is about thirty inches in width, and strikes N 55° W. The rock in mass has a dark greenish colour, and weathers with a rough exterior; a fresh surface shows a minutely crystalline structure, and here and there a few small grains of pyrite. Under the microscope, in a thin slice, I found it to be composed as under—

(1.) Felspars which form a network—or, perhaps, more properly, groups—in which several crystals are in juxtaposition with others at various angles. They are much eroded, and more or less filled by alteration products; and of these epidote in granular masses, and of a pale yellow colour, is the most frequent. It often replaces a large part of the crystal. Another alteration product is kaolin. Minute flakes of some chlorite mineral are also very frequent in these felspars. The optical measurements which I was able to effect in a few of the least altered felspars gave for the zoneOP $- \infty \breve{P} \infty$ from 3° 30′ to 10° 15′. The crystals are either compounded according to the Albite law, or more rarely simple. The long and narrow forms of these crystals show that the elongation has taken place in the direction of the edge $\infty \bar{P} \infty - \infty \breve{P} \infty$

(2.) Among and between the clustered felspar prisms are numerous crystals showing the usual external angles of amphibole, but having only the faintest traces of prismatic cleavage. In sections which might be considered near the clinopinacoid I obtained measurements of the inclination of the plane of vibration as high as 18° 30′. This mineral is polychroic, the colour of the three rays being, however, in light shades—

c = green ; b = light green ; a = pale yellow.

Associated with the amphibole are numerous rectangular crystals resembling magnetite, but, as some of them are surrounded or partly composed of a somewhat opaque grey material, they may rather be titanic iron, and the grey material leucoxene. The large percentage of TiO_2 shown in the annexed analysis agrees with this view.

Some yellow crystalline grains with rugged surfaces suggest sphene.

Besides these constituents there are, in spaces between the other crystalline minerals, radial masses of some chlorite mineral, which is, however, clearly distinguishable from the other chlorites produced by the alteration of amphibole, and I suspect that it may represent portions of basis.

The sequence of formation of minerals in this rock is not quite clear, but the probability is that the order has been as follows:—(1.) Titanic iron; (2.) amphibole and plagioclase, these two not differing perceptibly in period of formation.

I subjoin a quantitative analysis of this rock, but, in the absence of more precise knowledge of the composition of the numerous alteration products, I have not found it practicable to calculate satisfactorily the mineral percentages. All that I can say with safety is that the felspar is probably a more basic one than is found in those rocks which I have already described.

This rock was most probably, in its unaltered state, a diorite standing near to the hornblende porphyrites.

No. 7.—Diorite.

	Per cent.	Molecular Proportions.		Ratio.	
P_2O_5	... tr				
CO_2	... ·44	... ·20	SiO_2, &c. =	26·42 ...	7·
TiO_2	... 1·39	... ·34			
SiO_2	... 47·63	... 25·88			
Al_2O_3	... 17·20	... 3·34	R_2O_3 =	3·79 ...	1·
Fe_2O_3	... 3·60	... ·45			
FeO	... 8·09	... 2·25	RO =	7·67 ...	2·
MnO	... tr	... —			
CaO	... 6·42	... 2·30			
MgO	... 6·25	... 3·12			
K_2O	... 1·31	... ·28	R_2O =	4·79 ...	1·3
Na_2O	... 4·65	... 1·50			
H_2O	... 2·71	... 3·01			
	99·69	32·13			

Hygroscopic moisture, ·73 c 212° F.
Pyrite (FeS_2) ... ·53
Specific gravity ... 2·893

(*f.*) *Diabase.*

The only instance which I have met with of a rock which did not belong to the diorite group is that of a strong dyke traversing the quartz-mica-diorites near the junction of the Mount Elizabeth branch with Navigation Creek. Examined in a thin slice, I found it to have the following composition :—

(1.) Iron ores in crystals showing rhombic sections, and all more or less surrounded by a grey, somewhat obscure, material (leucoxene).

(2.) Plagio-felspars extended in the direction of the brachypinacoid, and compounded according to the Albite law, more rarely the Pericline law in interposed lamellæ. I could not obtain any satisfactory measurements of the inclination of the plane of vibration. The larger crystals have their edges and corners rounded off.

(3.) Pale yellow augite in ill-formed crystals and groups of crystalline grains. Some of this augite has been converted into a pale green chloritic mineral, and much more into a very pale yellow epidote. In several cases there are crystals remarkable for being partly composed of felspar and augite, the latter being interposed so that the axis "c" coincides in each case, and the angles formed by the plane of vibration in the two minerals are diverse and characteristic of each.

I observed one solitary instance of a very small brown-coloured and dichroic section of a mineral having the prismatic cleavage of amphibole. It was almost surrounded by a chloritic alteration of augite, and may itself be an alteration product of that mineral.

(4.) Prisms of apatite plentiful.

There is no great improbability that a rock such as this should appear among the most basic of the rocks of an area such as Noyang. This dyke occurs under just the same conditions as dykes of the more basic diorites, and the main distinction between it and them is in the more elongated character of the felspars, and the occurrence of augite instead of hornblende.

This rock terminates the series which I have collected to illustrate the igneous rocks of Noyang. The whole series is parallel to that of which the quartz-porphyries are characteristic, the only difference being in the preponderance, in the Noyang group, of a soda felspar, and in the other of a potassa felspar. The presence of albite, or of an oligoclase standing very near to it, as the characteristic felspar of this series is peculiar; and it is interesting to observe that, taking the crystalline-granular rocks as the starting-point, there is a decrease in basicity from an oligoclase to albite, and at the same time a more marked decrease in the general basicity of the rock by the disappearance of the Mg Fe minerals, so that at the end of the series the white quartz-porphyrites are composed almost wholly of albite and of quartz.

IV.—The Sedimentary and Metamorphic Rocks.

The igneous rocks which I have now described form, in the aggregate, a great mass which has left the traces of its intrusion in the changes produced in the physical and molecular condition of the sediments with which it came in contact.

The normal strike of the Silurian sediments of the district may be taken as about N 30° W, but I find that in the neighbourhood of this intrusive mass the strike of the sediments has been diverted to nearly east and west. This is not an isolated case, for I have observed the same deflection of the normal strike adjoining intrusive areas at Swift's Creek, Dargo Flat, and other places in Gippsland. This shows the enormous disturbance of the earth's crust which accompanied the extravassation of the once molten masses.

This deflection of the strata east and west is observable at Shady Creek, about three miles from the contact. The dip to either hand is so slight that, practically, the beds may be looked upon here as vertical. The alteration observable in these alternating sandstones and slates is an induration generally, and a slightly spotted appearance of some of the more fine-grained beds. Narrow veins of quartz, with traces of chlorite, are very frequent. From this point, in going southwards, the sediments soon resume their normal appearance, and no igneous rocks reappear, the Silurian strata disappearing at a distance of about ten miles underneath the marine tertiaries. To the north the sediments become more and more altered into contact schists as they approach the Noyang area.

I prepared several slices from samples collected at Shady Creek, and also from the northern side of the range of hills across which the old line of road leads to Noyang.

Shady Creek.—I found a sample of one of the fine-grained beds to have the following composition:—The slice was prepared parallel to the bedding. It is mainly composed of overlapping more or less rounded plates of a colourless or faintly green mineral. In places where these plates are seen edgeways, they are twisted, bent, ragged edged, and very slightly dichroic, and where numerous form what may not inaptly be called a "foliation." When the rock is examined between crossed nicols, these plates behave like sections of a uniaxial mineral, and this comes out much more clearly when a Klein's quartz-plate is used. The characters of this mineral suggest strongly that it is chlorite. In this mass are numerous small grains of quartz, and a considerable amount of black granular material, which is probably carbonaceous.

A second slice I prepared from one of the coarse-grained sandstones of Shady Creek. The ground-mass of the rock is composed of materials precisely similar to those of the last described sample, that is, mainly of a chloritic mineral and minute grains of quartz; but there are, in addition, a few large flakes of muscovite mica. The only microliths are a few very small, stout, colourless prisms, and a few yellow granules, and some carbonaceous material. In this "paste" there are very numerous angular fragments of quartz, and angular and rounded fragments of felspar. These fragments are of such size, as compared to the remainder of the rock, as to give it a pseudo-porphyritic aspect.

The quartz is such as is found in the crystalline-granular granite rocks, and contains numerous and very minute fluid cavities. Some of the fragments of felspar have all the appearance of orthoclase, others are plagioclase, and in one fragment of the latter I observed the angle formed by the plane of vibration in either side of the twin composition face to be 40°.

Besides the fragments of quartz and felspar which form the greater part of the rock, there are also several rounded fragments which are yellow in colour, contain iron ores (magnetite?), and are isotropic. They have, in fact, exactly the appearance of a volcanic glass, which I believe them to be. There are also some fragments of green tourmaline, and a good deal of brown iron ore generally distributed through the slice. This rock has therefore been formed from the detritus of igneous rocks, which were probably developed both in crystalline and vitreous forms. The examination of a rock such as this suggests that an investigation of the most coarse-grained of the Silurian beds of Victoria might, perhaps, give some insight into the nature of the still older formations of which at present, so far as I am aware, nothing is known. At any rate, it seems that in Gippsland those formations on which the Silurian sediments were laid down, and from whose waste they were most likely formed, have completely disappeared during the metamorphic and plutonic processes to which the palæozoic rocks have been subject.

I prepared several other slices, which did not afford me any special points of interest, being either the same as, or intermediate to, the above.

Northern Side of Shady Creek Range.—The first sample which I examined has, in the hand specimen, a finely-foliated structure, and a silky lustre on the bedding planes or foliations, and also a few slightly marked spots like incipient "nodules." Under the microscope I found this rock to be composed as follows:—

(*a*) Foliations of almost colourless thin overlapping plates, which react as a uniaxial mineral.

(*b*) Foliations alternating with (*a*), composed of the first-mentioned colourless uniaxial mineral, together with flakes of a brownish yellow mica, which in places predominate almost exclusively.

(*c*) Black granular material, most of which I judge to be carbonaceous—possibly some may be magnetite. This is heaped together in places.

Another slice prepared from a sample which was not so markedly foliated, I found to be composed almost entirely of the chlorite-like mineral, with here and there isolated flakes of colourless mica (muscovite ?). These were disposed in two directions, so as to produce a net-like effect in the slice. I observed herein also a few stout short prisms of green tourmaline, and much carbonaceous material, and some hydrated iron ore.

In none of these samples did I observe the thorn-like microliths which are so plentiful in some slates.

In proceeding up the course of the Tambo River from the Noyang ford, the contact of the igneous and sedimentary rocks is found at the junction of that river and the Haunted Stream. In following up the Tambo from this point the appearance of contact metamorphism decreases, until the hornfels rocks gradually are replaced by highly inclined alternating sandstones and slates of much the normal appearance and strike. In selecting a sample for examination I endeavoured to choose one which should be as much as possible in an unmetamorphosed condition; for, at a short distance northward, the formations again show change, and this time gradually assume a character which places them with the regionally metamorphosed schists of Omeo.

The beds from which I selected a sample had a strike of N 55° W. I found them fine-grained and fissile; in colour a dark green, but in all cases slightly spotted by the peroxidation of their iron. A thin slice which I prepared did not, however, bear out the impression I had received from an inspection of the rocks in position. The uniaxial colourless chloritic mineral which is so common a constituent of many of these fine-grained rocks was almost absent, and its place was taken by another colourless micaceous mineral, in rounded plates, with often ragged edges. This mineral, although biaxial and somewhat resembling muscovite, does not polarise with the brightness of that mineral, which also exists in small amount in the same rock. The double refraction of this mineral is rather weak.

A large part of the rock is made up of minute quartz grains. In addition to these constituents there is hydrated iron ore, and much black granular material, which is not affected by long digestion in hydrochloric acid, but is removed by ignition of the slice, and which, therefore, is carbon.

The following analysis is of part of this sample, and the calculation of the percentages has been based upon the microscopic examination:—

No. 8.—Slates.

	Per cent.	Molecular Proportions.	Ratio.		
P_2O_5	·23	·03			
SiO_2	62·30	20·71	SiO_2	=	20·71
Al_2O_3	19·22	3·73	R_2O_3	=	3·95
Fe_2O_3	1·80	·22			
FeO	4·01	1·11			
CaO	·44	·16	RO	=	2·75
MgO	2·95	1·48			
K_2O	3·60	·77			
Na_2O	2·07	·67	R_2O	=	3·06
H_2O	2·36	2·62			
	98·98	31·50			

Hygroscopic moisture, ·40
Specific gravity ... 2·727

SLATES.

	P_2O_5.	Si. O_2.	Al_2O_3.	Fe_2O_3.	Fe O.	Ca O.	Mg O.	K_2O.	Na_2O.	H_2O.	Sum of Molecular Proportions.	Sum of per cents.
	·03	20·71	3·73	·22	1·11	·16	1·48	·77	·67	2·62	31·50	..
Apatite ..	·03	..	..	..	..	·10	..	..	..	..	·13	·51
Limonite ..	..	..	..	·22	..	..	..	..	..	·33	·55	2·10
Muscovite ..	..	2·08	1·04	..	..	..	..	·52	..	·52	4·16	14·50
Chloritoid ..	..	2·69	2·69	..	1·11	·10	1·48	·25	·67	1·77	10·76	33·99
Quartz ..	..	15·94	..	..	..	..	..	..	..	..	15·94	47·82
Totals ..	·03	20·71	3·73	·22	1·11	·20	1·48	·77	·67	2·62	31·54	98·92
Differences	..	..	..	..	..	+·04	..	..	..	..	+·04	..

This calculation shows a probability that the remainder, after providing for the muscovite-mica on the basis of ·52 Mol. of K_2O, gives a chloritic mineral of the constitution 3 SiO_2, 3 R_2O_3, 3 RO, 3 R_2O, with a surplus of 15·94 Mol. of SiO_2 for the quartz. This rock, therefore, has the following percentage composition, disregarding the apatite and the limonite:—

Chloritoid	35·29
Muscovite	15·05
Quartz	49·66
	100·00

And the micaceous minerals are, to quartz, very nearly in the molecular proportion of 1· to 1·

Near the contact of the quartz-mica-porphyrites and the sediments at the Haunted Stream, about two miles from the Tambo River, I found fine-grained beds resembling those just described, and, as in the other case, alternating with sandstones. The dip was here N 10° W at 80°. I found this rock to be made up in great measure of the uniaxial chloritic mineral which I had before observed in the Shady Creek rocks, together with muscovite, which here again was disposed in two directions, producing a net-like appearance. Together with these were some quartz grains and ores of iron, magnetite, and brown iron ore.

In the same neighbourhood, but somewhat nearer to the Tambo River, I found the sediments more metamorphosed. One which I examined I found to be of the following composition:—(1) Angular grains of quartz, with a few minute fluid cavities; (2) brown mica in small flakes; (3) a little colourless mica, perhaps muscovite.

At the junction of the Haunted Stream with the Tambo River, I found the contact schists well developed. For some half mile up the river the schists are traversed by joints dipping east at about 25°. At the contact itself the bedding planes of the sedimentary rocks are almost obliterated, but where I could make it out I found the bedding to be at high angles on a strike east and west. The schists are traversed by a number of strong porphyritic dykes. I observed inclusions in the quartz-mica-diorites at the immediate contact, which somewhat resembled the dark-coloured patches which are so common in these rocks. These, however, were true inclusions of foreign rocks, and not merely aggregations of the more basic elements of the diorites. I examined a slice prepared from a dense black fragment included in the quartz-mica-diorite at the immediate contact. I found it to be a metamorphosed sandstone, exactly similar to some occurring at Swift's Creek. It was composed of (1) quartz grains, (2) muscovite, (3) biotite. I have placed these in the order in which they are relatively as to amount. The only peculiarity in this sample is that the biotite mica is, in places, almost wholly aggregated together, leaving other spots free from it. Besides these three principal constituents, there were numerous minute flakes of brown mica scattered throughout the whole slice, and of such minute size as to be little more than mere microliths.

In order to compare, if possible, the most altered with the least altered rocks, I selected an example of a finely crystalline hornfels, which seemed to nearly represent the less altered rock which I have examined and analysed (No. 8). Of this I prepared slices, and carried out a quantitative analysis.

Under the microscope I found it to consist of the following minerals :—(1.) Angular quartz grains, with their longer diameters approximately parallel. (2.) Biotite mica in brown ragged flakes, forming foliations, but also scattered through all the rock. This mica is dichroic in shades of brown. (3.) A colourless mica, in long rectangular flakes, having the characters of muscovite. (4.) A chlorite mineral in small aggregations, filling-in spaces in the mass ; it is pale green, and not sensibly dichroic. (5.) Brown iron ore ; and (6.) a few small prisms of tourmaline.

The subjoined is the quantitative analysis of the same rock:—

No. 9.—HORNFELS.

	Per cent.	Molecular Proportions.		Ratio.
P_2O_5 ...	·16 ...	·02		
SiO_2 ...	61·92 ...	20·60	= SiO_2 ...	20·60
Al_2O_3 ...	20·74 ...	4·03	= R_2O_3 ...	4·31
Fe_2O_3 ...	2·28 ...	·28		
FeO ...	3·90 ...	1·08	= RO ...	2·38
MnO ...	·17 ...	·05		
CaO ...	·42 ...	·15		
MgO ...	2·19 ...	1·10		
K_2O ...	2·28 ...	·49	= R_2O ...	3·97
Na_2O ...	3·51 ...	1·13		
H_2O ...	2·12 ...	2·35		
	99·69	31·28		
Hygroscopic moisture	·92			
Specific gravity ...	2·738			

The subjoined calculation of the mineral percentages agrees with the results of the microscopic examination, with the exception that the combined water is in excess, and that there is a small deficiency in the alumina. These discrepancies are probably due to analytical inaccuracy.

HORNFELS.

	P_2O_5.	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MnO.	CaO.	MgO.	K_2O.	Na_2O.	H_2O.	Total Molecular Proportions.	Total per cent.
	·02	20·60	4·03	·28	1·08	·05	·15	1·10	·49	1·13	2·35	31·28	..
Apatite	·02	..	..	..	..	..	·06	..	..	..	..	·08	·33
Limonite ..	..	..	..	·08	..	..	..	..	..	..	·16	·24	·78
Lime-Mica ..	..	·22	·22	..	..	..	·09	..	..	·09	·04	·66	2·36
Potassa-Mica ..	..	·98	·49	..	..	..	..	..	·49	..	..	1·96	7·861
Magnesia-Iron-Mica ..	..	6·92	3·36	·10	·83	·05	..	·85	..	1·04	·69	13·84	47·57
Chlorite	..	·30	..	·10	·25	..	..	·25	..	..	·40	1·30	3·46
Quartz	..	12·18	..	..	..	..	..	..	..	..	..	12·18	36·54
Total	·02	20·60	4·07	·28	1·08	·05	·15	1·10	·49	1·13	1·29	30·26	98·88
Differences ..	..	..	+ ·04	..	..	..	..	..	..	..	–1·06	–1·02	–·81

The lime-mica which is here indicated may perhaps be included in the minute scaly aggregates. Disregarding the small amount of apatite, considering the ferric hydrate as extraneous, and including the small amount of chlorite with the mica, we have the following composition of the rock :—

Micaceous minerals	62·63
Quartz	37·37
	100·00

—the micaceous minerals being, to the quartz, in the molecular proportion of 1·46 : 1·

The Omeo road from Noyang follows, for some distance, the contact of the sedimentary and igneous rocks along Navigation Creek. The alteration here is mainly an induration, thereby producing a hard flinty-looking rock, differing in appearance somewhat from the normal hornfels. On examining a thin slice, I found it to consist almost entirely of grains of quartz of different sizes, even down to mere dust. With this there was a very little brown mica. Many of the larger quartz masses were not only compound, but increased in size by secondary quartz which, also generally diffused through the rocks, gives it its indurated appearance. At the foot of the Fainting Range, however, the quartz-mica-porphyrite mass has produced much more marked effects—that is, if one can be quite sure that the alteration is wholly due to its influence, and not in some measure to previous metamorphism ; for it is on the northern side of this range that the schists commence to assume an appearance which is more like that of the less metamorphosed members of the regional schists, than those contact rocks which I have described herein.

At the summit of the Fainting Range the sedimentary rocks have a wrinkled schistose structure, the bedding vertical on a strike of N 70° W. This character is maintained down the range southwards to near their contact with the quartz-mica-porphyrites, where the dip of the schists is to N 10° E at 75°. They are penetrated at this place by several large dykes proceeding westward from the igneous mass.

I prepared several samples from this contact, and I found them to be somewhat peculiar forms of hornfels. One sample was composed mainly of angular quartz grains, set together with only slight traces of bedding in a material which had been altered to a micaceous mineral in aggregates of minute, brightly polarising scales. Besides this there were also well-marked flakes of muscovite. Throughout this rock there are numbers of the minute oval or rounded brown and colourless microliths, which I have found very frequently in the most altered of the quartzose hornfels rocks. I treated a slice of this rock with hydrochloric acid, with occasional boiling, for a month. I found the ores of iron removed, the scaly micaceous aggregates dull and evidently much acted on, but the muscovite and the minute microliths were quite unaffected. The scaly aggregates are probably of some chlorite mineral.

Another sample I found to be a foliated rock, the mass of which was composed of a micro-crystalline-granular aggregate, having the appearance of a mixture of quartz and felspar, associated with a colourless or pale green micaceous mineral. In this mass I observed angular quartz grains, some of which were fractured, so that the parts were no longer optically in accord with each other. Surrounding all the larger quartz grains, I observed a margin of secondary quartz, which was not always in accord with the nucleus. In examining these quartz grains, it seemed singular that the oval or rounded microliths, which are probably mica, are often within the quartz substance. Their formation thus in the substance of a quartz grain seems at first sight inconceivable. The observation that these quartz grains consist of an original centre, and a subsequently deposited exterior, removes the difficulty, and shows that these mica-microliths could have been formed during the metamorphism of the rock, and then sealed up by the secondary quartz. With these quartz fragments were also pieces of felspar—angular fragments lying with their longer diameters according to the foliations. I am unable to decide whether or not to consider these as examples of the regeneration of felspars from sedimentary material. Their peculiar appearance, and their manner of arrangement favours this, and indeed there is no *a priori* reason that I know of against such a regeneration in contact schists; but the fact remains that such instances are of extreme rarity.

In following down the Tambo River from the Noyang ford, the contact between the igneous rocks and the sediments is found where Rainy Flat Creek joins the river. The sediments at that place are converted into well-marked varieties of quartzose and micaceous hornfels, such as those which I have already described. The hornfels has a dip to S 10° E at

67°, and is traversed by two systems of well-marked joints, one dipping N 60° E at 30°, and the other S 55° E at 42°, and these are so marked that it requires an examination of the texture of the rock to determine that they are joints, and not bedding planes.

The metamorphism of the sediments continues for several miles down the valley of the Tambo River, showing the neighbourhood of the intrusive rocks, which then reappear in a somewhat peculiar form as a crystalline-granular compound of quartz and felspar, almost wholly devoid of mica or hornblende. The composition of these rocks is that which, under favourable circumstances, might have consolidated as a quartz-porphyrite, such as are seen near Noyang.

I prepared some slices of these rocks, and I found them, as their appearance in the field had indicated, to be composed essentially of felspar and quartz, with very slight traces of a brown magnesia-iron-mica. The felspars were of three kinds: one highly compounded according to the combined Albite and Carlsbad laws, and with small angles formed by the plane of vibration with the composition face, in one case so small as almost to coincide with the twin plane. The second felspar was evidently orthoclase, and was kaolinised. The third felspar was microcline. A little chloritic mineral is distributed through the whole rock.

The quartz in this sample fills in large spaces, and is remarkable for the numerous microliths it contains. Many of these are of some chlorite mineral, some are ores of iron, and some have even the appearance of felspar fragments. Fluid cavities were not numerous.

Another sample which I collected at a further distance I found to be less quartzose, more felspathic, and to be also entirely free from mica. The felspars were in large tabular crystals, which had slightly interfered with each other's growth. The best crystallised appeared to be oligoclase, and the least well-formed were microcline.

V.—Conclusion.

The age of the Noyang intrusive rocks must remain somewhat uncertain. All that can be stated with any degree of certainty is that they are younger than the goldfields series of North Gippsland, and therefore probably younger than Lower Silurian. The geological structure of the district, and the relations of the palæozoic formations in it, cause me to believe that these intrusive masses date from the great age of plutonic disturbance that embraces the close of the Silurian and the greater part of the Devonian period. Thus the formation of these rocks would have taken place in an age which, in Gippsland, was one of great volcanic activity.* The occurrence of dykes and masses of quartz-porphyrites radiating from the same place where subsequently other masses of felsophyrite rocks (lavas) appeared, together with breccias, suggest that this spot formed one of the vents of a palæozoic volcano, whose site is now indicated by the great mountain mass of the Mount Elizabeth Range. It is not at all improbable that the enormous masses of ejected volcanic materials between Noyang and the Buchan River, some of which are within a distance of fifteen miles of the place I describe, may have in part been derived from this source.

The igneous rock masses of Noyang, as a whole, cover a far larger area than that which I have mapped and described, and are encircled, and I doubt not were once wholly enveloped, by the more or less altered Silurian sediments. These have evidently been subject to violent strains and compression, so that the bedding now lies in places at more than 45° to the normal strike of the district. These disturbed sediments have been invaded by the igneous rocks, which have not only truncated their horizontal extensions and have sent into them dykes and masses, but have also melted off and absorbed an unknown amount of the vertical extension downwards of the folded and compressed strata.

The igneous rocks which at Noyang thus intruded into the sediments varied as to their structure, but they all belong, with one exception, to the same petrological group, although formed at different and successive parts of the same period over which the invasion and metamorphism of the sediments extended and the subsequent cooling and crystallisation took place. The igneous rocks of Noyang must be considered as a whole. The several varieties of rock have been, no doubt, produced at different times, but these times have been merely parts of a great series of periods of activity and quiescence, and the difference in the composition and structure of the rocks thus formed must necessarily have depended in great

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* "The Devonian Rocks of North Gippsland," *Progress Report, Geological Survey of Victoria*, Part III.

measure on the continuously varying conditions thereby produced.

In considering what may have been their origin and the mode of their formation, it is evident to me that an explanation which disregards the influence of those contact sediments which have been absorbed into the mass of the crystalline rocks will be partial and incomplete.

The microscopical examination of the igneous rocks of Noyang brings out clearly one marked feature, viz., the decreasing amount of the Fe Mg minerals in the succeeding formations. The occurrence of more basic rocks as dykes at the close of the process is a small feature when compared to the whole. The analyses which I have given also show this decreasing amount of RO bases, and this is most marked in the latest of the quartz-porphyrites, which is essentially composed of albite and quartz alone.

Two explanations might be given of this decrease of basic minerals in succeeding rocks. It might be suggested that the successive emissions of rocks of less and less basicity represent the residues of the original magma from which the RO bases had crystallised out as magnetite, mica, or amphibole, and that thus the latest rocks represent the more acid residuum. But this view fails to account for the amount of sediments which have certainly been absorbed, and suggests that the earlier and more basic rocks owe at least some of their basic compounds to the sedimentary materials which have been absorbed. An inspection of the analyses Nos. 3, 4, 5, and 6 shows that absorption of rocks of such a kind would certainly add a comparatively large increase of the RO bases to the igneous masses. To see what might be the result of such a process, I have calculated and subjoin results on the assumption that equal portions of a magma of the constitution of the white quartz-porphyrite (analysis No. 6) and of a sediment (analysis No. 7) were combined. Such a magma would have a mean composition as given below :—